SPATIO-TEMPORAL VARIABILITY OF SNOWPACK PROPERTIES: COMPARING OPERATIONAL, FIELD, AND ICESAT REMOTE SENSING DATA OVER NORTHERN COLORADO, UNITED STATES

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ABSTRACT

Snowpack properties vary spatially and temporally. Three snow depth datasets are evaluated to assess this variability across different scales: operational station data, auxiliary field measurements and remotely sensed estimates from the Geoscience Laser Altimeter System (GLAS) lidar instrument that was aboard the Ice, Cloud and land Elevation Satellite (ICESat). The variability is best illustrated by the field measurements; spatially concurrent snow-off and snow-on ICESat overpassed are rare so the satellite estimates are more approximate while integrating over much larger support or footprint. The operational data cover the least area; even the snowcourse transects measured over 100s of metres show limited variability.

Index Terms— Snow, Variability, ICESat, GLAS

1. INTRODUCTION

Snow is a valuable resource in mountainous areas that provides water for 60 million people in the Western United States [1]. Snowpacks vary spatially over different scales as well as intra- and inter-annually, making it difficult to assess the distribution of snow in such areas. However, over small domains (e.g., several km^2) the meteorological variables that drive the distribution of snow, such as wind direction and solar radiation, tend to be temporally consistent over space. Similarly precipitation as snow can be considered relatively constant. Thus, many studies assume that snow distribution patterns repeat over time [2].

2. DATA AND METHODS

Here we examine the spatially patterns of snow from operational station data, auxiliary field measurements and remotely sensed estimates. The variability of snow depth data from these three data sources are examined for Joe Wright Creek at Cameron Pass in the Cache la Poudre watershed of Northern Colorado, United States.

Operational data are collected and maintained by the Natural Resources Conservation Service [3]. Manual snow depth measurements are taken monthly at 10 locations along a transect at the Cameron Pass snowcourse. Daily (and hourly) snow depth measurements are taken with an ultrasonic depth sensor with a reported precision of 2.5 cm at the Joe Wright snow telemetry (SNOTEL) station.

Since the operational data only represent a transect for a snowcourse and a point for a SNOTEL station, five additional snow depths measurements were taken adjacent to each snow course location. The 200 sets of field measurements were taken over a one square kilometre area surrounding the Joe Wright SNOTEL station.

2.1. Satellite-based Estimates

The remotely sensed snow depth estimates were derived from the Geoscience Laser Altimeter System (GLAS) lidar instrument aboard the Ice, Cloud and land Elevation Satellite (ICESat). These data are a transect with a repeat over the same area (e.g., Joe Wright Creek) of the earth of 90 days. The return from GLAS is a pixel that is approximately 70m in diameter and pixels are spaced at 180 m between centers. The data are in the public domain [4].

The elevation accuracy of GLAS data is 2 to 3 cm over flat surfaces, and as such have used to estimate ice sheet elevations [5]. Estimation of snow depths over sea ice has used estimate of the spectral properties of the snow to extract snow depth from ice thickness [6]. The combined thickness and depth was estimated from the freeboard or height above the sea [6]. However, [5] warned that snow depth was the greatest uncertainty in the conversion from freeboard to ice thickness.

Thus the estimation of snow depth in complex terrain is not trivial since repeat GLAS measurements are very rarely centered at the same location. Four approaches have used to estimate snow depth in complex terrain [7] with some success when compare to SNOTEL data in the Uinta Mountains of Utah, U.S.

Here, the global elevation data (GLA06 L1B) available from [4] are used to estimate snow depth over one transect within Joe Wright Creek. Snow off elevations were obtained from the October 10/2004 overpass and snow on elevations from the February 25/2005 overpass. When the centers of each pixel was within XXXXX metres, an snow depth was estimated from the simple difference of snow on minus snow off.

3. RESULTS AND DISCUSSION

3.1. Ground Data

Between the snowcourse and field measurements for May 1st/2010, the average snow depth was essentially the same (Figure 1), yet, there was greater variability for the additional field measurements than for the operational snowcourse samples. However, the coefficient of variability among the snowcourse 10 locations in 2010 was 9.8% or only about half of the 76 year average (Figure 2).

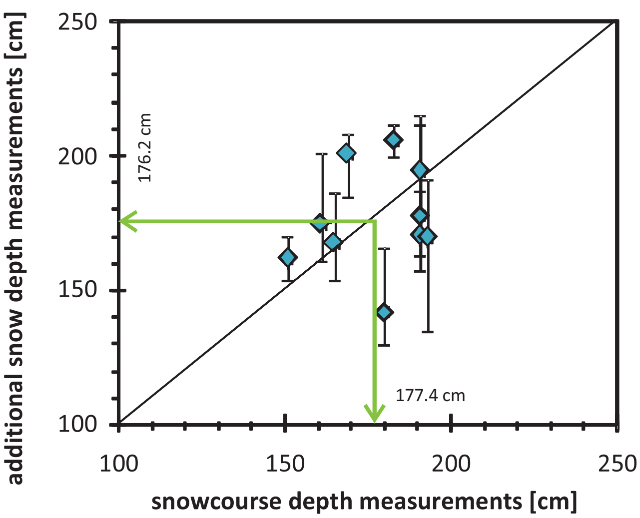

Figure 1. Snow depths at the Cameron Pass snow course on May 1st, 2010 for the operational data versus the additional field measurement adjacent to each snow course sample.

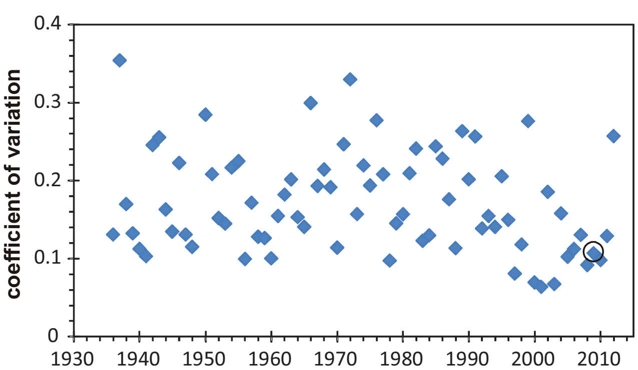

Figure 2. Snow depths coefficient of variability at the Cameron Pass snow course for the time series over April 1st, with 2010 highlighted to illustrate Figure 1.

The Joe Wright SNOTEL station overestimates depth around the one square kilometre area [8] and Figure 3. This is consistent over time due to the redistribution of snow along Colorado Highway 14, i.e., along the road.

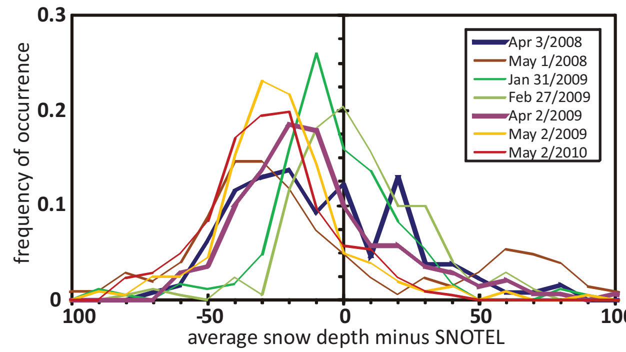

Figure 3. Comparison of field measurements versus the SNOTEL station, as per [8].

The results from the IceSAT GLAS comparison to the other data will be presented at the conference.

4. ACKNOWLEDGMENTS

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5. REFERENCES

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